Original Research Article

Efficiency of the combination of vermicompost and zero valent iron for the remediation of lead, copper and aluminum

ABSTRACT

Aims : Evaluate the efficiency of the combination of vermicompost and zero -valent iron for the remediation of two types of soil with lead, copper and aluminum.
study design : Observational technique and analysis of soil samples contaminated by mining.
Place and Duration of Study : It was applied in the greenhouse in the district of San Juan de Lurigancho and in the Casapalca mining industry located in the district of San Mateo, in the months of February and September 2023.
Methodology : The analysis of soil samples contaminated by mining was carried out through the addition of vermicompost amendments and zero -valent iron , seeking to observe the physicochemical changes of the soil and determine the bioavailability of lead, copper and aluminum in the soil. Using the atomic absorption spectrometer, a pH meter; the loss on ignition method, to determine organic matter; A 1.0mol L-1 ammonium acetate solution was used for the cation exchange capacity (CEC) of the soil and vermicompost and for the determination of total potassium (K) method 3050b acid digestion of sediments, sludge and soils was used. .
Results :
From the efficiency of vermicompost in the remediation of contaminated soils, a maximum removal of lead of 35.57%, copper 29.60% and aluminum 27.62% was obtained from the Casapalca soil with vermicompost amendment and Fe° 5:1, repetition 1 and 2. The greatest efficiency of the dose of zero valent iron for the remediation of contaminated soils was given at a ratio of 3:1 with a dose of 3 kilos of soil + 60 Fe° and LC (45 g Fe° + 15LC). Also, the absorption of plants from 2 months of the *Cucumis harvest sativus* (cucumber) in the remediation of contaminated soils was efficient for the three types of metals with a dose of 5:1, observing that for Al there was a greater absorption in all cases.
Conclusion : The application of vermicompost is efficient in the different types of doses applied.

Keywords : [efficiency, vermicompost , zero valent iron , remediation]

1. INTRODUCTION

Rapid economic and demographic growth leading to inadequate disposal of waste and effluents thereby contaminating the environment with heavy metals is a major concern (Nzeveb et al., 2020). Heavy metals act as toxic substances for soil and crops at high levels. Heavy metals hardly biodegrade in the soil and tend to be transferred to plants and subsequently affect human health (Seleiman et al., 2020), this affects the growth, morphology and metabolism of soil microorganisms since They cause the denaturation of proteins or the destruction of the integrity of cell membranes. (Govindarajan et al., 2010).
For all these reasons, it is extremely urgent to safely eliminate or manage industrial waste using clean, new, low-cost and eco-friendly technologies for remediation (Bhat et al., 2017), as is the case of vermicompost, which combines the functions of the worms, crush and condition the substrate, making this process faster, with microorganisms, responsible for the biochemical degradation of organic matter (Aira & Domínguez, 2009).

Stabilization with the application of organic amendments is effective for the immobilization of heavy metals (Hamid et al., 2020). Earthworms help in the bioremediation process, removing heavy metals from the soil and accumulating them in their body tissues, especially in the yellow cells. Depending on the concentrations of heavy metals, the body of the earthworm is affected. (Jatwani et al., 2016).
Mining pollution causes adverse effects on agricultural spaces since they have high concentrations of toxic elements (Cano, 2021). Due to the effect of precipitation, these present contaminants are dispersed in the soil due to runoff, thus having an adverse effect on agriculture and biodiversity (Tun-Canto et al., 2017). Heavy metals modify the physicochemical properties of the soil, as well as high concentrations of toxic elements, which leads to negative impacts on the environment and human health. (Rivera et al., 2020).

2. METHODOLOGY

Soil sampling was carried out at the Casapalca mining unit, following the following steps:

2.1 Selection of sampling areas

Areas with different levels of contamination by lead, copper and aluminum were identified and selected. Soil samples were taken at each sampling site according to established sampling guidelines.

2.2 Initial soil characterization

The physical and chemical characteristics of the soil were determined, as well as the initial concentrations of lead, copper and aluminum. For the analysis of the physicochemical properties of the soil and amendment; Firstly, to determine the Hydrogen potential (pH) in the soil, LC and Fe° samples , a pH meter was used in a 1:2 ratio according to METHOD 9045D, for the organic matter test it was carried out by mass loss by ignition. the CIC by the ammonium acetate method. The determination of metals and total potassium was determined by METHOD 3050B. For this, the METHOD 3050B method is used. (determination of metals), where 1g of soil samples previously sieved 2 mm are weighed, then digested at 95 °C with royal solution with cc $HNO3$ + HCl 2:6; Make up to 100 ml with distilled water and filter with Whatman No. 41 paper, and then take the readings to the atomic adsorption spectrophotometer. To determine the organic matter, the Loss on Ignition method was used. where 5g of soil sample previously dried at 105 °C is weighed, to then be calcined in a muffle at 850 °C x 4 hours and then weighed at constant weight. Afterwards, for the loss on ignition, the sieved soil sample is weighed, a 1:2.5 (W/v) dilution is made with distilled water, having sufficient quantity to take the reading on the previously calibrated pH meter; using METHOD 9045D SOIL AND WASTE pH, Hydrogen potential (pH). For the cation exchange capacity (CEC) of the soil with vermicompost , it was determined using a 1.0mol L-1 ammonium acetate solution.

2.3 Preparation of vermicompost and zero valent iron

Vermicompost was prepared from organic waste and zero- valent iron following standardized procedures.

2.4 Monitoring and analysis

Monitoring is carried out after 2 months to reach the soil water retention capacity and another 2 months for the growth of Cucumis. sativus (cucumber) in pots. Once this period has concluded, the plants will be harvested and the analysis units taken to the laboratory.

2.5 Analytical instruments

Use the analytical instruments mentioned above to determine the effectiveness of the combination in remediating heavy metals.

2.5 Data analysis

Analyze the data obtained to evaluate the efficiency of the combination in reducing heavy metal concentrations in the soil. Perform statistical analyzes to determine the significance of the results.

2.6 Interpretation of results

The results were interpreted critically and contextually, considering the soil conditions and the characteristics of the applied combination. Finally, the laboratory results of both the physicochemical properties and the determination of the bioavailability of metals in the 6 types of treatments will be determined. First, the physicochemical properties of the soil will be determined, such as pH with a potentiometer, organic matter with the oxidation method, and CEC with acetate. Then, 1kg samples for each treatment will be taken to the laboratory and the bioavailability of metals present in the samples will be determined using an atomic absorption spectrophotometer (ICP-OES).

Table 1. Methods used

NUMBER	METHOD
1	Atomic absorption spectrometer METHOD 3050B ACID DIGESTION OF SEDIMENTS, SLUDGES, AND SOILS
2	The pH was determined with a pH meter METHOD 9045D SOIL AND WASTE pH
3	The organic matter was determined using the Loss on Ignition method.
4	The cation exchange capacity (CEC) of the soil and vermicompost was determined using a 1.0mol L^{-1} ammonium acetate solution .
5	Determination of total potassium (K) METHOD 3050B ACID DIGESTION OF SEDIMENTS, SLUDGES, AND SOILS.

3. RESULTS AND DISCUSSION

3.1 Vermicompost dose efficiency

The greatest efficiency for the remediation of soils contaminated with lead, copper and aluminum occurs with a dose of vermicompost of 3:1, with 3 kilos of soil + 60 LC and Fe ° (45 g LC + 15 Fe °); obtaining the greatest reductions in Pb from 942.6 mg/kg to 698.5 mg/kg in its final concentration, also for Cu from an initial concentration of 462.4 mg/kg, 323.8 mg/kg was obtained in its final concentration and for Al from a concentration of 9190.2 mg/kg resulted in 6823.8 mg/kg. This is because the combined action of earthworms and microbes mineralizes organic waste and transforms it into manure, reducing contamination in the soil (Sharma and Garg , 2023). While with a dose of 1:1 with 3 kilos of soil + 60 LC and Fe° (30 g LC+ 30 Fe°) the remediation was lower, reducing the metals Pb, Cu and Al slightly; This is as shown in table 2 where for the Casapalca soil with vermicompost amendment and Fe° 1:1, for Casapalca soil with vermicompost amendment and Fe° 1:1 repetition 1 and the Casapalca soil with vermicompost amendment and Fe° 1: 1 repetition 2 the reductions were from 969 mg/kg initial to 720 mg/kg final for aluminum, 952.5 mg/kg initial to 701 mg/kg final for aluminum and 952.7 mg/kg initial to 700 final for aluminum respectively.

For Cu the reductions were from 462.2 mg/kg to 367.2 mg/kg, 461.8 mg/kg to 357.8 mg/kg and 462.3 mg/kg to 358 mg/kg. For the metal Al, the reductions were from 9096 mg/kg to 7085 mg/kg, from 9095.5 mg/kg to 7085.2 mg/kg and from 9095.4 mg/kg to 7084.5 mg/kg. For aluminum it was reduced from 9096 mg/kg to 7085 mg/kg.

With a dose of 5:1 the efficiency of vermicompost for remediation is reduced, achieving a minimum reduction of the metals Pb, Cu and Al from 985.8 mg/kg to 838.2 mg/kg for Pb, from 460.5 mg/kg to 335.2 mg/kg for Cu and from 9090 mg/kg to 7583.5 mg/kg for Al.

Table 2. Metal removal efficiency (Pb, Cu and Al)

		Removal %		
	Code	**Pb**	**Cu**	**To the**
		End	**End**	**End**
Original ground control	SC-C	11.54	10.67	5.80
	SC-C-R1	11.52	10.24	5.59
	SC-C-R2	11.54	10.43	5.61
Soil with zero valent iron amendment	SC- Fe°	28.02	23.18	15.47
	SC-Fe°-R1	27.98	23.24	15.47
	SC-Fe°-R2	28.08	23.34	15.45
Soil amended with vermicompost	SC-LC-	17.76	18.15	12.27
	SC-LC-R2	17.63	18.04	12.26
	SC-LC-R2	17.65	17.79	12.25
OE1.-efficiency of the vermicompost dose for the remediation of soils contaminated with lead, copper and aluminum	SC-L1F1	25.70	20.55	22.11
	PS-L1F1-R1	26.40	20.53	22.10
	SC-L1F1-R2	26.52	19.79	22.11
	SC-L2F1	25.90	27.79	25.75
	SC-L2F1-R1	26.01	27.68	25.77

	SC-L2F1-R2	25.90	27.81	25.75
	SC-L5F1	35.57	29.16	27.57
	SC-L5F1-R1	35.09	29.23	27.61
	SC-L5F1-R2	34.11	29.60	27.62
OE2.-efficiency of the dose of zero valent iron for the remediation of soils contaminated with lead, copper and aluminum	SC-F1L1	25.90	19.96	22.97
	SC-F1L1-R1	26.01	20.35	22.91
	SC-F1L1-R2	25.90	20.31	22.94
	SC-F2L1	17.67	18.33	15.24
	SC-F2L1-R1	17.66	18.19	15.15
	SC-F2L1-R2	17.73	18.22	15.23
	SC-F5L1	14.97	27.21	16.57
	SC-L5F1-R1	14.97	27.21	16.57
	SC-L5F1-R2	14.97	27.21	16.57

3.2 ZERO- valent iron dose efficiency

The greatest efficiency of the dose of zero valent iron for the remediation of contaminated soils occurs at a ratio of 3:1 with a dose of 3 kilos of soil + 60 Fe° and LC (45 g Fe° + 15LC).
In contrast, with a 5:1 dose of zero iron, the reduction of all contaminants is slight; Pb decreased from 985.8 mg/kg to 838.2 mg/kg, Cu decreased from 460.5 mg/kg to 335.2 mg/kg and Al decreased marginally from 9090 mg/kg to 7583.5 mg /kg. Which is refuted by Huang et al. (2017), who points out that technologies based on zero -valent aluminum for the elimination of heavy metals due to its properties allow efficient remediation of contaminated soils, since it can help immobilize metals and prevent their absorption by plants and soil organisms. .

3.3 Plant absorption in the remediation of contaminated soils

Regarding the absorption of plants in the remediation of contaminated soils, it was high at a dose of 5:1 with 3 kilos of soil + 60 LC and Fe ° (50 g LC + 10 Fe °) 5:1 for all cases of the metals.
Being thus demonstrated for lead with a dose of 50 to 10, it presented a significantly greater absorption compared to the other doses , in the same way for copper and aluminum with removal percentages of 53.96% for lead, 39% for copper and 66.31%. for aluminum. Such a result being supported by Atiyeh et al. (2000), who explains that the efficiency of vermicompost is attributed to its ability to improve plant growth by enriching the soil with nutrients and organic compounds; since, in their study, the interaction between humic acids and the decomposition processes of organic waste resulted in an improvement in the soil structure and the availability of essential nutrients for plants.

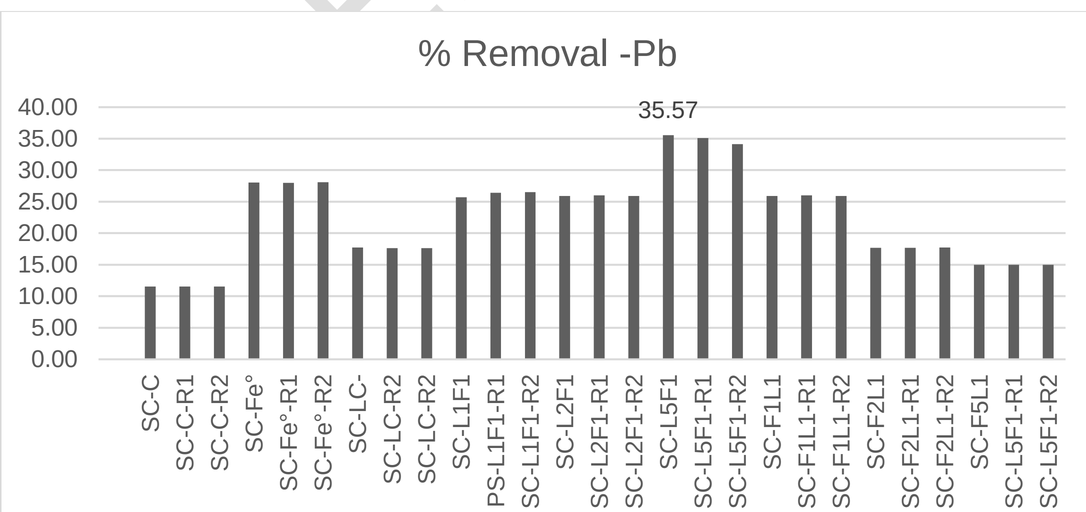

Fig. 1. Lead removal

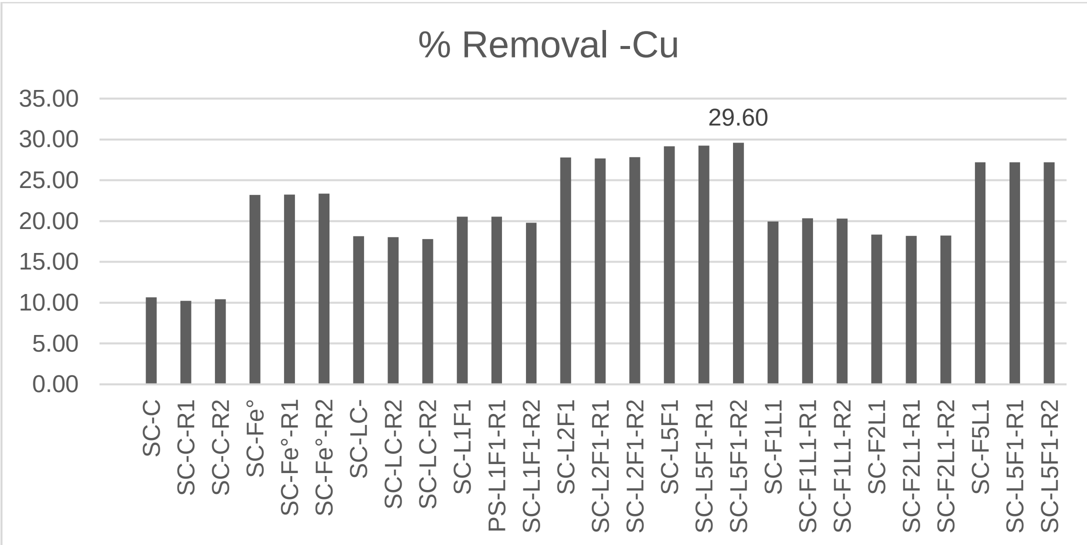

Fig. 2. Copper removal

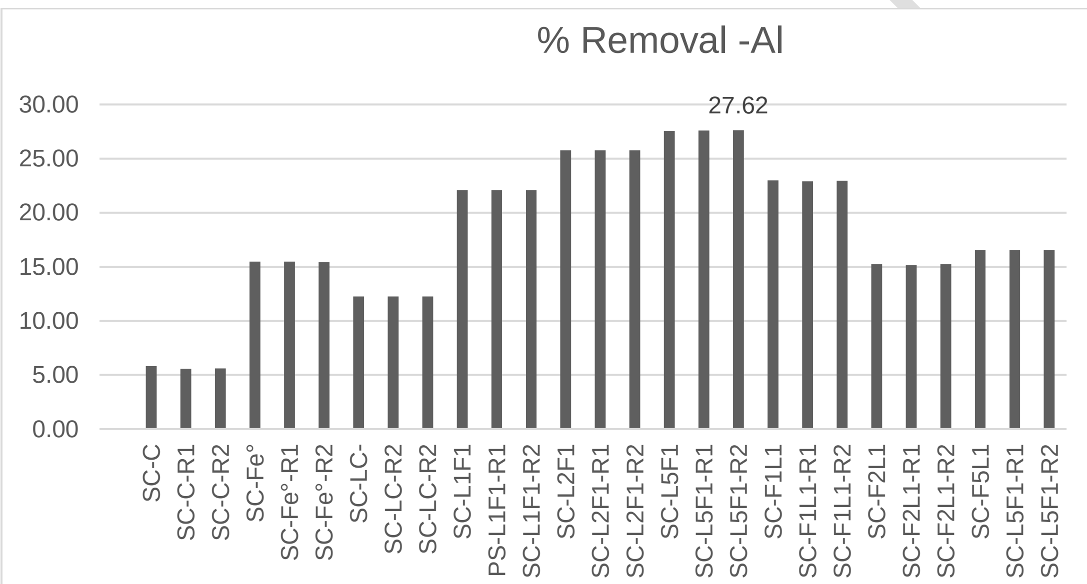

Fig. 3. Aluminum removal

4. CONCLUSION

The application of vermicompost is efficient in the different types of doses applied, but for greater removal it should be applied at a ratio of 3:1 (3 kilos of soil + 60 LC and Fe ° (45 g LC + 15 Fe °)). Likewise, the efficiency of the dose of zero valent iron for the remediation of soils contaminated with lead, copper and aluminum is ideal in conditions of 3 kilos of soil + 60 Fe° and LC (45 g Fe° + 15LC) 2:1 .

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